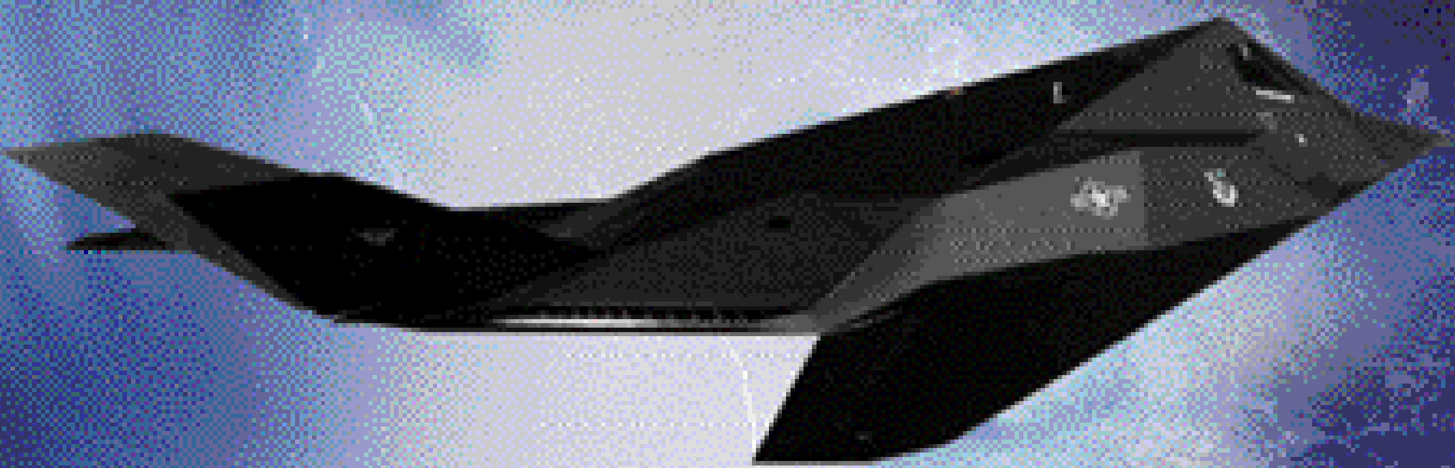
AIRCRAFT SURVIVABILITY

Spring 1999



JTCG/AS

Low Observables & Countermeasures

Complementary Capabilities

Aircraft Survivability is published by the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS). The JTCG/AS is chartered by the Joint Aeronautical Commanders Group.

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Editor's Notes

We'd like to welcome a member to the Central Office staff. Army LTC Charles Schwarz replaces LTC Paul McQuain as the Army's military representative and the new Director. His recent assignments include tours at Headquarters Army Materiel Command as a Procurement Staff Officer for Engineer Mine-warfare Equipment and Non-system Training Devices; the Pentagon, in the Strategic Defense Initiative Organization now known as Ballistic Missile Defense Organization as a Program Integrator; and again at Headquarters Army Materiel Command in the Inspector General's office.

LTC Charles Schwarz

Professor Ball at the Naval Postgraduate School has published an article in the November-December 1998 issue of *Naval Aviation News*. The article is titled, "Designed to Survive". If you don't have the magazine, the article is on the web at, http://www.history.navy. mil/nan/1998/1298/survive.pdf. Professor Ball also has a survivability education web site at, http://www.aircraft-survivability.com.

Mark your calendars for the annual Survivability Symposium sponsored by the National Defense Industrial Association (NDIA) which will be held 16-18 November, 1999 at the Naval Postgraduate School in Monterey, CA. The theme for this year's event is, Aircraft Survivability 1999: Challenges For The New Millennium.

The JTCG/AS is investigating the idea of developing a Spacecraft Survivability discipline. Dr. Joel Williamsen of the University of Denver Research Institute (UDRI) and formerly with NASA, is working with the JTCG/AS and the AIAA Survivability Technical Committee to promote this objective. The concept is to extend the discipline of aircraft survivability into the regime of spacecraft design and operation, to protect spacecraft assets from undirected threats (meteoroid and orbital debris) and directed threats (kinetic energy, directed energy, nuclear, and other anti-satellite weapons).

As part of the space survivability initiative, the JTCG/AS is in the preliminary stages of planning a workshop to explore the applicability of aircraft survivability methodologies and test data to the growing concern of spacecraft survivability. Possible co-hosts could include USSPACECOM and AIAA. The tentative date is June 2000 and would be held at the USAF Academy, Colorado Springs, CO. If you would like more information, Dr. Williamsen may be contacted at 303.871.4502 or email jowillia@du.edu. Or, you may call the JTCG/AS Central Office. More to come in upcoming issues of *Aircraft Survivability.*

Since our last issue, the JTCG/AS co-hosted with the Missile and Space Intelligence Center (MSIC) a successful workshop titled, National MANPADS Workshop: A Vulnerability Perspective. The workshop was held in Huntsville, Alabama 15-17 December 1998. Over one hundred experts attended a technical interchange to assess if there is anything more the survivability community should or could be doing to make aircraft more survivable against the MANPADS threat. The next issue of the newsletter will focus on the theme of Aircraft Vulnerability against the MANPADS threat.

Joseph P Jolly

Lethal and Survivable Air Weapons Systems: Essential Today and Tomorrow

by VADM William J. Fallon, USN

The air warfare dimension of our national military capability is indispensable today and a prime consideration in every strategy and contingency in the political-military arena. This emphasis is warranted because we enjoy a significant advantage over potential adversaries in our ability to dominate airspace. Our ability to influence events worldwide, to prevent actions detrimental to national interest, and to respond decisively hinges on speed and agility. Air-launched weapons from tactical platforms provide that ability and are high on the list of preferred military options. Forward deployed and rapid response air forces working jointly and increasingly, in combined operations with our allies, provide the nation with a valuable and reusable capability. But to be credible, these forces must be effective, survivable, and affordable.

Background

The collapse of the Soviet empire and end of the Cold War has resulted in a fundamental redefinition of the term "security." No longer is there a superpower military standoff in an essentially bipolar strategic setting, but complex, interdependent economic, political, military, and population issues punctuated with a continuing series of regional conflicts and ethnic strife.

Although U.S. combat forces have been reduced by some 35 percent over the past 9 years, the operational tempo for our troops, manifested in forward presence, crisis response, and regional engagement operations, is higher than during the Cold War. Additionally, the Department of Defense (DoD) allocation of gross domestic product (GDP) is only about 3 percent, down 50 percent since 1986 and at the lowest level since 1948. DoD topline spending and research, development, test and evaluation (RDT&E) are down 34 percent and 26 percent, respectively, since 1987.

There is certainly room to debate the appropriate allocation of resources within the budget. But, there is no doubt that the amount of money in the DoD budget is sharply less than a decade ago–and unlikely to significantly increase in the near future, absent a big change in the strategic landscape.

In spite of these factors, we have been operating very well, thanks to the procurement and readiness investments of the early 1980s. Current replacement levels for equipment, however, are clearly insufficient and readiness of our nonforward deployed forces is eroding. Over the past 25 years, the cost growth curve of new fighter and attack aircraft, measured in cost per pound, has been increasing steadily and is at about 7 percent, compared to 3-4 percent for various new ship and land equipment designs.[1] This steep and steady cost escalation is making it increasingly difficult to acquire replacement aircraft in the numbers required by the services.

Discussion

To ensure that our air forces are effective, survivable, and affordable, we must plan for the future. Consideration must be given to employing a combination of devices and techniques to enable us to successfully complete our missions. The use of electronic warfare (EW), low observable (LO) applications, and precision guided munitions (PGM) will aid in attaining this goal. For 60 years, EW has been a factor in combat operations, with a heavy involvement in tactical aviation for the last 30 years. The focus of the avionics industry has been on the hardware of threat receivers, warning devices, jammers, deception devices, expendables; discussion about self-protect or strike support; pod or integrated, onboard and off-board techniques, and related tactics.

LO applications are newer, in service for only 20 years, and less mature. Primarily the purview of the airframe contractors, these applications have seen limited service to date having been reserved as "manned silver bullets," in the form of F-117s and the newer B-2. But LO will be a major factor in aircraft survivability in new strike fighter designs and should be employed for all future tactical aircraft.

The public domain has an interesting perception that equates LO to stealth; stealth to invisibility; invisibility to invulnerability; invulnerability to 100 percent survivability. Of course, this is an inaccurate picture that has become a major factor in employment decision-making and produces high public expectation of success. EW is less glamorous and less well understood than stealth and generates much less public interest.

Another very significant operational factor is the rapid ascent of PGMs to a position of overwhelming preference for nearly every planning contingency today. The development and use of PGMs of various ranges, profiles, and capabilities are closely related to aircraft survivability factors and should be a design consideration.

Expectations among airwing designers and aircrews have become more reasonable regarding LO and EW applications. Few in the business today regard any single device as guaranteeing full survivability. Most combat aircrews train to employ a combination of techniques to complete missions with high assurance of returning home.

The Way Ahead

To successfully incorporate LO and EW applications, we must first ensure that the task or mission is well defined. This is straight forward for tactical air, i.e., destroy the opponent's aircraft before the opponent destroys you and put weapons on ground targets to destroy them. The next issue is to enhance survivability when completing these missions. The approach to accomplishing survivability should be coordinated, systemic analysis of mission execution from launch to recovery. This requires a "mental open architecture." For example, we should be–

- Looking at the big picture first to determine the opponent's functional tasks, e.g., detection, acquisition, targeting
- Working the seams to delay or deny information
- Looking at the full spectrum of the mission with the philosophy that no single application is going to guarantee survival, but several well-integrated, mutually supporting, or complementary applications could do the job.

Other factors, such as the ability to integrate intelligence feeds and combat identification data, would enhance the functionality and techniques of discreet EW equipment to boost survivability.

Airframe layout, signature reduction, and EW techniques have been used to enhance survivability but rarely coordinated optimally or well integrated from initial design concept into operational use. Instead, techniques have been presented singularly in the form of external pods, internal boxes, or reprogrammable programs, just to mention a few. There are in fact too many dysfunctional solutions.

If DoD and industry agree to work closer together from the beginning, that relationship will be enhanced by the following:

- Methods of modeling and simulation that have been vastly improved
- Techniques that enable products to be manufactured at significant cost and time savings
- Industry groups exchanging information in a more efficient manner as a result of the existence of fewer aerospace companies.

Along the way there are challenges to overcome:

- Reliability and maintainability of avionics equipment and coapplications
- Issues with antennas, apertures, and transmissivity
- Excessive time in development
- Cost of applying the solutions.

When addressing theses challenges, all types of aircraft should be considered as well as the ability to upgrade without wholesale component replacement. For the future, unmanned aerial vehicles (UAV) could redefine survivabil-

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Aircraft Survivability:
A Balanced Susceptibility Reduction Approach

by Mr. Robert T. (Tom) Webber

Many in both the operational and aircraft survivability communities incorrectly use the words "survivability," "susceptibility," and "vulnerability" interchangeably. From the pilot or operational commander's viewpoint, survivability is the watchword. They want the aircraft and pilot to return unscathed to fly another mission. Survivability is a combination of susceptibility (the ability of a threat system to successfully engage an aircraft) and vulnerability (the probability that an aircraft will actually be damaged when a missile passes close enough to the aircraft to fuse). An aircraft can be made more survivable by reducing either its susceptibility to the threat system or its vulnerability to the detonated warhead, or a combination of both. Susceptibility reduction can be achieved by many methods. One method is electronic warfare (EW) [a broad category that includes countermeasures (CM)] low observables (LO), threat avoidance through mission planning, Suppression of Enemy Air Defenses (SEAD), and maneuvers.

From the pilot or operational commander's viewpoint, survivability is the watchwor d.
Photo by Denny Lombard and Eric Schulzinger

To maximize the reduction in susceptibility in a cost-effective design, we must examine the proper balance of all the available methods. Although many of these techniques have been in use for years, effective EW has been a primary consideration only since the Vietnam War. The application of LO is even more recent. To evaluate alternative concepts, we must accurately quantify the combined effects of these susceptibility reduction technologies.

The "Low Observables and Countermeasures—Complementary Capabilities for Aircraft Survivability" symposium, held in Monterey, CA in August 1998 was co-sponsored by the National Defense Industrial Association (NDIA) and the Association of Old Crows (AOC). The synergistic application of LO and CMs to reduce aircraft susceptibility was discussed at this symposium. The objective of the symposium was to discuss the leveraging effect of the integrated application of EW and LO to improve aircraft survivability, and how this balanced integration of technologies significantly surpasses the contribution of either concept applied separately. The presentations introduced many considerations necessary to achieve a cost-effective design through a balanced approach to susceptibility reduction. However, no one proposed a methodology to integrate these technologies to achieve a truly cost-effective system. Technology has advanced to a point where integrated LO/CM systems are not only feasible, but also are being built and tested. Many attendees indicated that the symposium was a first step toward achieving a joint capability within the community; however we still have a long way to go before the LO and EW communities will work together effectively on combined EW/LO concepts to achieve the most cost-effective designs.

The symposium showed that there is still too much of a "them versus us" (i.e., EW versus LO) attitude that blocks the way toward a truly integrated solution. The concept of integration (or balance) has not caught on at all program levels. However, some programs are leading the push toward achieving an effective EW and LO blend. In developing the F-22, numerous LO and EW concepts were considered in the trade studies that resulted in the effective balance evident in today's design, as briefed by Mr. Al Pruden at the Monterey Symposium. The JSF Program will demonstrate an even larger step in balancing EW and LO technology to achieve low susceptibility to the current and future threat as Lockheed-Martin and Boeing strive to develop an effective and survivable design, while meeting the many cost, performance, producibility, and maintainability requirements. Other balanced approaches may also exist in companies' proprietary concepts or within classified areas. Few presenters actually showed analyses that demonstrated the synergistic effects of integrating both technologies to achieve a result that is greater than either contributor; when they did, the LO community emphasized LO reduction with the use of EW to augment survivability where necessary, whereas the EW community emphasized a little LO to make the EW job easier.

One of the most important messages in the symposium was presented by Lt Gen George Muellner, USAF (Ret) (former Principal Deputy Assistant Secretary of the Air Force for Acquisition) in his remarks on the first day:

The greatest need is for a metric, a measure of warfighter utility, that can be used across both disciplines to effectively compare and trade LO and EW solutions.

The first step the community must take is to define and develop this metric and credible modeling and simulation (M&S) to quantify the value of alternative EW and LO concepts. The presenters who mentioned M&S believed that current M&S is inadequate to accurately quantify EW effects, particularly in the area of counter-countermeasures (CCMs). Some presenters also had similar comments regarding quantifying the benefits derived from LO.

Accurately quantifying this balanced solution (including aircraft performance and operational concepts, which were barely mentioned at the symposium) is necessary to develop future military aircraft that are truly cost-effective, survivable systems.

The cost factor needs more in-depth study. Most people do not consider the "True, Full Cost of EW" when discussing the cost of LO. Lt Col Bob Gierard USAF (SAF/AQL), presented a paper on *The Cost and Comparative Effectiveness of EW and LO.* He demonstrated that when the total costs of EW Systems and LO Systems capable of performing similar missions (including supporting systems) are compared, their total costs are similar.

Some attendees did not support Lt Col Gierard's conclusion, which demonstrates why the survivability community must develop and agree on a methodology to correctly determine and assess the true costs of the combined EW and LO system approach to survivability. If the combat objective is the destruction of a specific target, all costs and penalties associated with accomplishing that objective with each design must be considered. Thus, cost is not only the procurement dollars of an aircraft. Other considerations are weight and performance changes; cost of supporting forces, SEAD, expendables, and lost aircraft; and the possible cost of delays in achieving the required objective (such as putting other forces in harm's way).

Where do we go from here?

Unfortunately, we have barely scratched the surface with this symposium. I hope that this article has generated additional insight and interest in this subject. We must work together to clear some of the hurdles identified here and at the symposium. I would like to hear the thoughts of the survivability community. As a member of NDIA's Air Combat Survivability Division's Executive Board, I will act as a clearing house for your ideas and present them at a future symposium. ✦

Biography

Mr. Webber is the Manager of the Lockheed Martin Skunk Works' System Requirements and Analysis Division. This Division is responsible for developing and justifying the requirements for all Skunk Works Programs, as well as quantifying the resulting survivability and effectiveness of these systems. He received a B.S. in Engineering from UCLA, and an M.B.A. from Pepperdine University. He was recently awarded the 1998 Air Combat Survivability Leadership Award for his work in developing analysis methodology of low observable (LO) concepts. He presently serves on the National Defense Industrial Association (NDIA) Air Combat Survivability Division's Executive Board. He may be reached at 805.572.7011 or tom.webber @lmco.com.

Integrated Low Observables and Countermeasures

by Mr. Ron "Mutz" Mutzelburg
Mr. Tony Grieco

Readers of this publication are usually focused on a single aspect of aircraft survivability. When this focus becomes so narrowed that the other survivability components are lost from the field of view, "stovepiping" may occur. In this manner, low observables (LO) and electronic warfare (EW) have tended to become stovepipes resulting in a lack of communication between the two technical communities.

To the casual observer, LO and EW are perfect candidates for stovepiping because they appear to be opposites. If one (perfect) system existed, a second would not be needed. If you could not be seen, you could not be easily hit with guided weapons. On the other hand, if you could spoof a guided munition, it would not matter if you were seen.

Further, LO and EW can interfere with each other. EW requires antennas; to work, EW systems need to take in information, so that disinformation can be sent out. However, the LO designer, does not like antennas because they create an additional cross section, which is not wanted.

Given the limitations on resources—specifically, money-coupled with the stovepipe mentality, a natural rivalry developed. The budgeteers quickly bought into the idea that if you had LO, you would not need money for EW. Money would be saved, they reasoned, to be allocated to other priorities. Consequently, EW lost funds.

The problem is that neither perfection nor invisible aircraft exist. Given enough money, however, engineering perfection, that is enough to accomplish the mission, can be achieved. Yet, the entire situation evolved because of a lack of funds.

If enough money were on hand to do whatever anyone wanted, stealth would clearly be the way to go. Build the most invisible aircraft that technology would allow, and equip the force structure with it. Despite Winston Churchill's comment that "nothing in life is so exhihilarating as to be shot at without result," it is better that the first shot never be fired. If our force can accomplish its mission without having defensive missiles launched, the pilots will avoid the intense stress that comes when a missile is in the air.

The Real World

There has never been enough money to do what we wanted to do because the budgeteers compete between EW and LO. Yet, the situation has worsened. Our defense budget is at its lowest point—as a fraction of the gross national product (GNP)—since before Pearl Harbor. If we are to have the best force possible for limited dollars, we must cease the competition between LO and EW and begin working together.

A notional trade-off curve between the cost of better LO or better EW, with aircraft survivability held constant, might resemble a "U." Going toward "perfect" LO to achieve survivability could break the bank, whereas going toward "perfect" EW does the same. However, a cost minimum might exist somewhere in between. Therefore, we might be able to search for a cost-effective solution that permits our military to wage war but return home afterwards. You may call this solution Cost as an Independent Variable (CAIV), or simply consider this as applying solid systems engineering principles to the problem of aircraft survivability.

Our fictitious curve will depend clearly on the platform and its mission. Further, the suggested trade-off ignores the type of LO (e.g., frontal, all-aspect) and types of EW (e.g., on-board, stand-of). Drawing a valid curve will require a good model, that which is one of our shortfalls.

We also must consider life-cycle cost, along with development and initial acquisition. As we strive for "perfect LO" and/or "the ultimate EW suite," the cost of supporting these systems escalates dramatically.

Model Development

To ensure that we can do valid and robust cost/benefit trade-offs, the current state of modeling must be improved. LO effectiveness modeling tends to be reasonably tractable with excellent examples from Air Force Studies performed by federally funded R&D centers, such as IDA and Rand. With respect to EW, we now use "Greybeard" round tables to codify the effects of defensive electronic countermeasures (ECM) for modeling purposes. We must do better. Although the authors do not have a favorite solution, we were encouraged with results from the Susceptibility Model Assessment and Range Test (SMART) project, funded by (D, TSE&E). Perhaps that project could be continued or institutionalized.

At the End of the Day

Survivability encompasses not only LO and EW but also tactics, vulnerability, and extent of standoff. Arguments have been advanced, however speciously, that if we had perfect LO or EW (or a combination of both that did the same thing–no hits on the aircraft from guided weapons) we would not need vulnerability reduction.

We find those arguments disingenuous. United States experience in Southeast Asia showed that we lost about 50 percent of our aircraft to fuel-related events. Designing an aircraft without fire suppression does not appear wise if our LO/EW solution is not totally robust or if the enemy gets a lucky hit. Furthermore, some aircraft have missions that dictate that they fly low and slow, and not enough LO and EW exists to ensure no hits; therefore, they also need vulnerability reduction. ❖

Biographies

Mr. Mutzelburg received his B.S.I.E. from Wayne State University and his M.S. in Industrial and Systems Engineering from Ohio State University. He is the Deputy Director for Air Warfare within the Office of Strategic and Tactical Systems, Under Secretary of Defense for Acquisition & Technology. Mutz is responsible for acquisition oversight for the B-1, B-2,C-17, F-22, F-18, JSTARS, numerous air-to-air and air-to-ground weapons and numerous other aeronautical programs.He may be reached at 703.697.8184.

Mr. Grieco has over 35 years of experience in EW.He received his M.S.in Engineering Management from the University of California, a M.S. in Electrical Engineering from the University of Missouri and a B.S. in Electrical Engineering from Fresno State College.Anthony is the Deputy Director, Electronic Warfare, Strategic and Tactical Systems Office, Under Secretary of Defense for Acquisition and Technology. He may be reached at 703.697.3619.

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ity. They are becoming more capable and should replace manned vehicles for many tasks being performed today. They also must be survivable.

One last point. Information operations are overshadowing hardware. We must have credible airframes, but the speed and agility of information are gaining importance over massed metal. It may be possible to inflict greater loss on an adversary using information rather than missiles.

Conclusion

The bottom line of military operations today is weapons on target. Survivability is a product of signature, aircraft vulnerability, countermeasures, and integration of multisource information and weapons. An integrated, systemic, balanced approach to survivability offers the best payoff. Let us leverage our technical strength, experience, and industrial savvy to our advantage and move forward now. ❖

Footnotes

[1] Dev Zakheim, *Trends in Military Spending and Weapons Systems Costs*, SACLANT Seminar Presentation, June 1998.

Biography

Vice Admiral William J. Fallon is a graduate of the Naval War College, Newport, RI, the National War College in Washington, D.C. and has a M.A. in International Studies from Old Dominion University. He commanded Attack Squadron SIXTY FIVE embarked in USS DWIGHT D.EISENHOWER,Medium Attack Wing ONE at NAS Oceana, VA, and Carrier Air Wing EIGHT in USS THEODORE ROOSEVELT during Operation DESERT STORM in 1991. He has been Commander, SECOND Fleet and Striking Fleet Atlantic since November 1997. Vice Admiral Fallon may be reached at 757.444.2422.

Author's note: Administrative and research assistance provided by LCDR Todd J. Flannery, USN COMSECONDFLT Staff.

Pioneers of Survivability

Hubert "Hugh" Drake

by Mr. Dale B. Atkinson

One of the unheralded pioneers of aircraft survivability is Hubert "Hugh" Drake. Hugh made major contributions to survivability, specifically to the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS.) Because he was a person who did the job without looking for praise, he did not receive sufficient recognition for his many contributions. Hugh is now going to receive that recognition.

Hugh joined the U.S. Navy as a reservist in January 1955 and attended Interior Communications Electricians School. He spent the majority of his Navy time onboard an Auxiliary Transport Demolition ship (a destroyer escort) that carried Navy Seals and Marine Raiders. He spent 9 months of his shipboard time in Japanese and Chinese waters before his honorable discharge in January 1957. He entered college the day after his discharge.

Hugh's path to the field of aircraft survivability was somewhat roundabout. Following his June 1961 graduation from California Polytechnic College at San Luis Obispo, with a B.S. in mathematics and a minor in electronics, Hugh joined the Boeing Company in Seattle, Washington. Here he became a first line supervisor in February 1962 responsible for the intersite circuitry development for the first five wings of the Minuteman I missile. He moved to Honeywell Corporation in Hopkins, Minnesota, in February 1964 to support ordnance development and transferred to the Micro-Switch Division in 1965 to establish an engineering analysis capability. In February 1966, he moved to the Naval Weapons Center (now Naval Air Warfare Center Weapons Division) China Lake, California, to support weapons development.

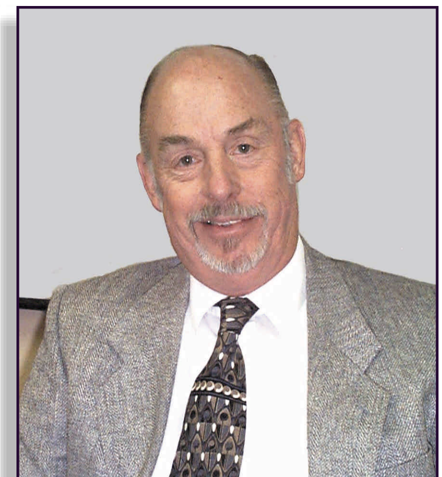
Hugh's first position at China Lake was as an operations analyst in the Warhead Branch where he was responsible for methodology development and lethality analysis. He became branch head in February 1968. He standardized warhead test and evaluation (T&E) data analysis procedures and characterization methodologies and was responsible for weapon system lethality analysis.

Shortly after joining China Lake, Hugh became interested in joint activities, which led him to the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME). The JTCG/ME was chartered in April 1966; one of its tasks was developing the Joint Munitions Effectiveness Manuals (JMEM). In the early days, the primary interest of JTCG/ME was air-to-surface and surface-to-surface munitions. Hugh joined the JTCG/ME in 1969 and, because of his interest in aircraft targets, became chairman of the Air Target Vulnerability Subgroup. To create more interest in air-to-air and surface-to-air missiles, Hugh established and chaired the Missile Evaluation Subgroup and later the Anti-Air Working Group which developed air target JMEMs and associated methodologies. Prior to that time, Hugh convinced Dr. Joe Sperrazza, head of Army Material Systems Analysis Agency (AMSAA) and Chairman of the JTCG/ME, to support the documentation of software models to minimize the proliferation of modeling and simulation (M&S.) More than 30 models were documented in an analyst's manual and a user's manual. These manuals played an important role in standardizing M&S in the JTCG/ME as well as in the later established JTCG/AS. In addition, Hugh was an active member of the international Tri-Partite Technical Coordinating Program (TTCP) working in this technical area.

Dr. Joe Sperrazza established a Survivability Committee under the JTCG/ME to give survivability advocates a forum for pushing to establish the

JTCG/AS and then played a role in convincing the JLCs to charter the JTCG/AS, which occurred on 25 June 1971. The Director Defense Research and Engineering (DDR&E) then funded the Test and Evaluation Aircraft Survivability (TEAS) Program so the JTCG/AS could address the survivability of the A-7, F-4, and AH-1 aircrafts. Dr. Sperrazza pressured the first JTCG/AS chairman to support quick response efforts to solve some of the aircraft loss problems in Southeast Asia.

The unexpected heavy combat aircraft losses experienced in the early stages of the Southeast Asia conflict led the Joint Logistics Commanders (JLC) to establish the JTCG/AS. Hugh played a major role in establishing the JTCG/AS and later became the second chairman of the JTCG/AS Methodology Subgroup. His task was to realign the subgroup from its focus on human factors to the methods needed to perform aircraft survivability assessments. He made major contributions toward getting the Methodology Subgroup focused on the right areas and initiating work on many of the models used today in survivability assessment. The JTCG/AS initially focused on vulnerability reduction but later addressed all aspects of survivability. One interesting experience Hugh had was attempting to bridge the gap between electronic warfare (EW) and the rest of survivability. This attempt met with resistance from the EW side, which held the opinion that the JTCG/AS should concentrate on vulnerability and leave EW to the experts. With time and new players, this viewpoint changed significantly; and the JTCG/AS Susceptibility Subgroup now routinely addresses EW and has made major contributions to this area over the years. Hugh's contributions in initiating these changes were manifold.



Hugh wishes to acknowledge that his accomplishments during his days in survivability owed much to the outstanding joint service personnel who worked with him. Hugh says, "They fought hard for the program and performed in an outstanding manner." Hugh jokingly says if he did one thing well it was "attempting to set a standard of (1) early to bed, (2) minimizing after-hours frivolity, (3) keeping everyone's nose to the grind stone, and (4) maintaining a gung-ho image." As Hugh emphasizes, "Those working with me worked hard, played hard, and accomplished a significant amount of work." Hugh says that rumors that he used unscrupulous methods to gain consensus from his working groups were all greatly exaggerated.

Hugh's career took a turn when in 1980 the China Lake Technical Director asked him to take over responsibility for the Electronic Warfare Test and Evaluation Simulation (EWTES) Division, commonly referred to as Echo Range. Hugh directed the range (involved in EW test and evaluation) through a get-well program requiring a coordinated approach involving in-house resources as well as NAVAIR, OPNAV and user commands including COMOPTEVFOR, VX-5, TOPGUN, DET WHIDBEY, and other Navy organizations. He established a Navy Tri-Lab committee to oversee simulator development and supported the Crossbow Committee. Hugh spent the next 3 1/2 years orchestrating a get-well program. He worked long days and long weeks. His one regret was his work did not leave time to pursue joint service programs. After the successful Echo Range get-well program, Hugh was selected as associate department head of the Electronic Warfare Department, where he was directly responsible for oversight of EW development programs (involved in antiradiation weapons and electronic systems RDT&E) and maintained direct liaison with SPAWAR, NAVAIR, OPNAV, and OSD. He was also a member of the Fallon, Nevada, training range fleet project team. He established the department's Long-Range Planning Office in 1987, where he headed the Navy Tactical Training Range Roadmap Committee and

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Electronic Warfare and Low Observability Technology to Defeat RF and IR Threats

by Mr. Dan Gobel

The blending of electronic warfare (EW) and low observables (LO) offers unique operational opportunities and operational challenges. By reducing and controlling a platform's passive signature and emissions, new or previously developed EW technologies and techniques may now be feasible where once they were not. Existing warfare applications, such as stand-off jamming, and new warfare applications that were considered too power hungry or not robust enough may now be feasible. This success does not come without challenges. For example, how do we effectively marry a technology's concept of operations that was conceived in covertness (LO) with one that was conceived in overtness (electronic countermeasure [ECM] jamming)? This process requires a cost-effective balancing of the two technologies and may involve changes in operational employment concepts and tactics. Overall, the combined results are improved platform effectiveness and improved countermeasure robustness.

Common MOE is Fundamental

Blending these technologies requires establishing a best value for a platform. Establishing the best value will require defining a measure of effectiveness (MOE), mission success, that is common to both technologies and then optimizing the platform for mission success. For example, if the goal is to defeat the threat system in the context of the mission, this would require effective identification of the threat system's kill chain and then exploitation of the kill chain vulnerabilities. Robustness is achieved by not relying on the disruption of one element of the kill chain, but rather disrupting or degrading multiple kill chain elements. Note, that disrupting or degrading the kill chain may begin days before the mission in the context of information warfare or information control.

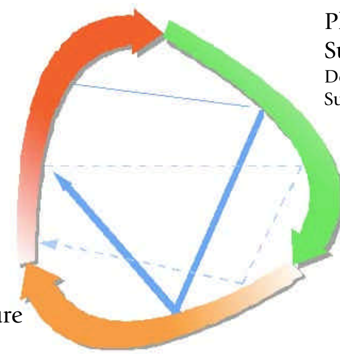

Figure 1. Response/Counter Response Design Evolution

Threat is Reactive

If the threat were constant, defeating the threat system would be simple. Unfortunately, threat improvement and countermeasure response is a continual response and counter-response (Figure 1). As threat lethality improves, platform survivability and mission success degrades, and a countermeasure response is necessitated. Traditionally, the countermeasure response has been jamming related. Recently, the countermeasure response can and will include defense suppression, dilution, signature reduction, and jamming. The objective is to establish a "low-cost" combined countermeasure response that will necessitate a "high-cost" threat response.

Traditional Responses No Longer Valid

The threat today is dynamic and responsive, representing the best that money can buy. Gone are the days of a homogeneous monolithic threat. Emerging is a rainbow threat that combines technologies and platforms from multiple countries and design philosophies. The export of advanced technology is now limited only by the buyer's pocketbook. It once took 10 to 15 years to proliferate advanced technologies to the third world; now, co-production and co-procurement accelerate the proliferation. Multispectral and super-agility summarize the threat capabilities of today and tomorrow. The threat continues to exploit the total radio frequency (RF) and infrared (IR) spectrum to minimize its vulnerability to single kill chain element failures. Threat agility exceeds the limits of manned aircraft, minimizing the traditional countermeasure tactics to out-maneuver or outrun the threat.

New Design Approach

Blending LO and EW technologies offers the ability to degrade the total susceptibility kill chain from delayed acquisition to increased endgame miss distance (Figure 2). The LO concept is to degrade the engageability of the platform by the threat by attacking the fundamental physics of the detection and track processes. Traditional EMCs rely on exploiting threat system design vulnerabilities and often use high-powered jamming to saturate or deceive the threat. Fundamentally, the concepts of operations of the two technologies are at opposite ends of the spectrum. Independently, both technologies are limited by affordability. Blending the two technologies will require philosophical changes in both communities. The EW community shift will be to develop countermeasures (CM) that work in concert with LO technologies. A shift in philosophy will be from overt to covert concepts for platform integration and countermeasure operation. This effort will include a greater emphasis on situational awareness: to manage the countermeasure timing or use, to manage platform observability, and to focus the countermeasure response. In addition, blending the technologies offers an ability to develop and integrate ECMs that exploit the benefits of signature reduction and offer techniques and technologies that attack the fundamental physics of the engagement. ✥

Biography

Mr. Dan J. Gobel is the Manager of Advanced Countermeasure Programs for Sanders, a Lockheed Martin Company. His responsibilities include the concept development, formulation, assessment, and demonstration of advanced RF and IR electronic combat systems for use on tactical aircraft, rotary wing platforms and military ground vehicles. Mr. Gobel has a Masters of Engineering in Operations Research from Southern Methodist University and a Bachelor of Science degree in Electrical Engineering from Purdue University. His work experience includes ten years of advanced aircraft program development, vulnerability analysis and design, and operations analysis while employed at General Dynamics, Fort Worth Division. He may be reached at 603.885.5382.

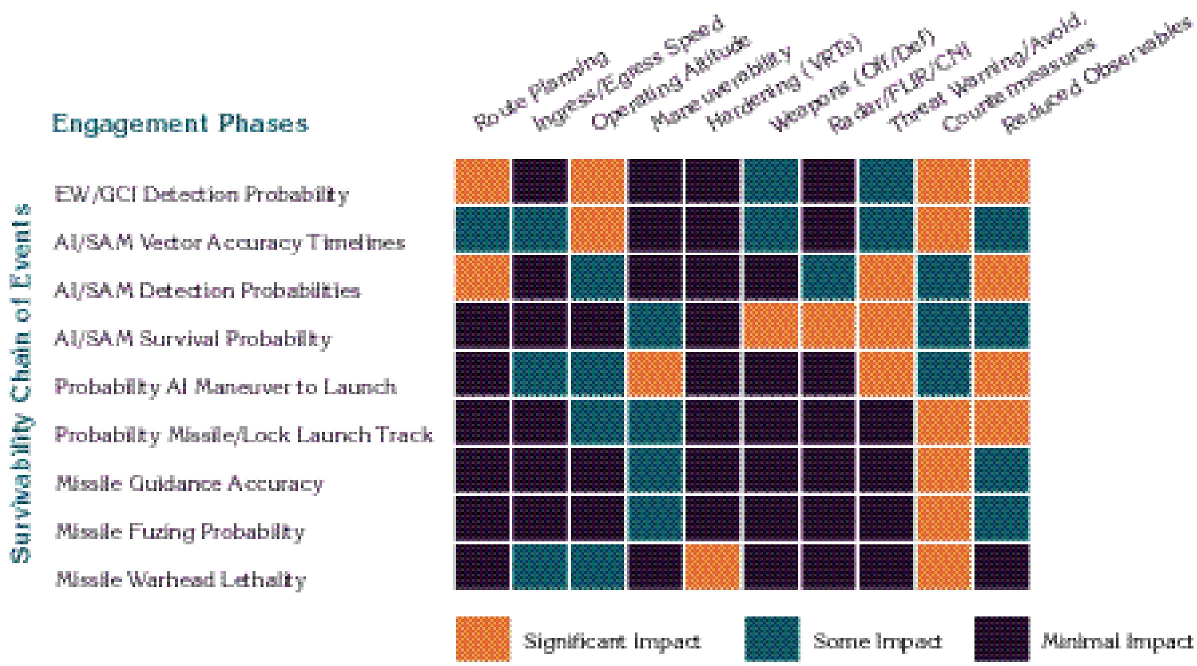

Figure 2. EW/LO Impact Every Phase of the Threat Engagement

The Survivable Rotorcraft

by Mr. David G. Harding
Mr. Stephen A. Brumley

Introduction

The superb effectiveness and survivability of today's modern scout/attack helicopter weapon system is based on a series of developments made since the late 1960s. This article traces the evolution of this weapon system to explore if it can survive in the future battlefield. Based on its history, the authors of this article believe modern scout/attack helicopters—with their unique combination of technology and operational tactics—will remain a vital force in the combined arms Army.

Initial development of today's helicopters began as a result of the shift in U.S. military focus from operations in Vietnam to involvement in the NATO alliance and the European Theater. Although more than 10,000 helicopters were sent to Vietnam, neither a significant armor threat nor significant air defenses existed within that theater. Consequently, there was no conviction these helicopters would have a role in addressing the mid- to high-intensity threat of NATO / Pact Europe.

The U.S. Army AMSAA addressed these helicopter survivability issues in its AMH1 studies and concluded that helicopters, although their losses may be high, could survive in the mid- to high-intensity AAA threat range. Meanwhile, the CDC/ISS studies were being conducted to help define the attributes of a new attack helicopter that would replace the canceled AH-56 Cheyenne. These studies included SRI-conducted battle simulations and also concluded that the combat effectiveness of the attack helicopter in the mid- to high-threat range would be positive. Both of these studies considered the ZSU-23/4, ZSU-57, and SA-7 as the primary threats to the attack helicopters.

To evaluate the effectiveness of the scout/attack helicopter team in the European threat environment, the U.S. Army, Europe, Canadian Forces Europe, and Federal Republic of Germany (FRG) forces conducted the Ansbach Trials. For the trials, the United States provided AH-1G attack helicopters with simulated TOW missiles, Canadians provided the OH-58C scout, and the FRG provided the armor force of Leopard tanks with its organic air defense—M-113/Vulcan and Redeye missiles. Trials were conducted in a free-play fashion over the

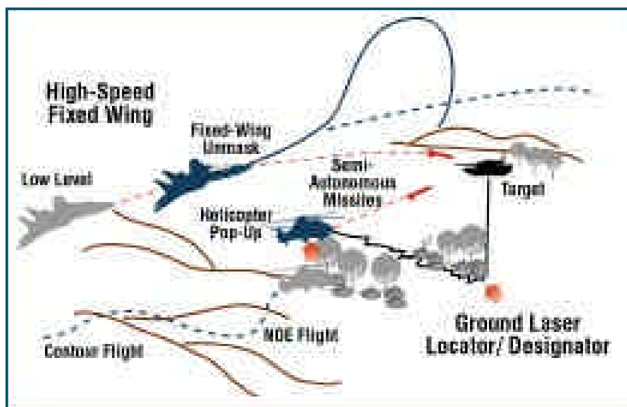

Figure 1. Rotorcraft Tactics for Ground Attack

Ansbach region and included three different tactical situations. For realistic attrition scoring, all players were equipped with an early version of the Miles Laser weapons simulators.

Operational tactics for the scout/attack helicopter were also refined during these trials. It was discovered the key to modern helicopter effectiveness was a change in tactics. Figure 1 illustrates the helicopter tactics used for a ground attack.

Rather than using the typical time-honored fixed-wing tactics of strafing attacks, the helicopter would be most effective if it employed hovering flight tactics at standoff ranges. Specifically, the scenario worked as follows—scout helicopters, transit-

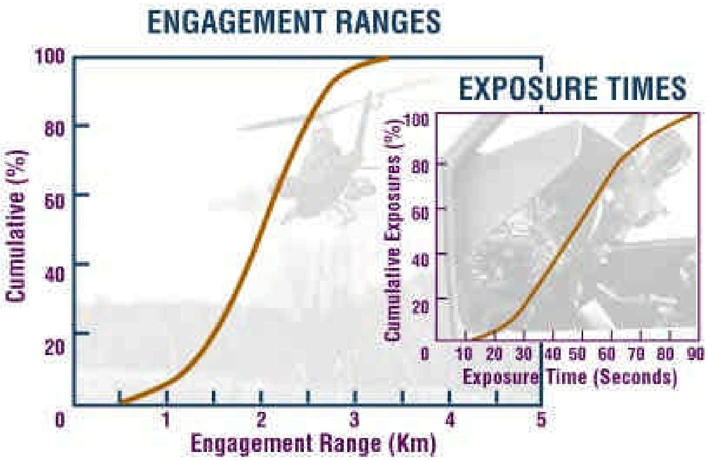

Figure 2. Ansbach Engagement Statistics

ing behind terrain mask, would pop-up and hover in brief exposures to view the region of interest while maintaining maximum standoff range. Multiple successive pop-ups of limited duration were conducted from different locations. To increase the difficulty of detection by opposing forces, exposure locations were chosen that provided a terrain, vegetation, or building backdrop to the helicopter.

The scout helicopters, having detected and located the targets, would then call in and direct the attack helicopters to fire. The attack helicopters then would use similar tactics as those employed by scout helicopters to conduct their attack. The limited duration of the helicopter's exposure to threats became the fundamental difference between effective helicopter versus fixed-wing attack tactics.

Fixed-wing aircraft with current weapons must fly a trajectory that allows line-of-sight for its sensors to search, acquire, identify, and lock-on to the target. Depending on the weapon, the fixed-wing aircraft must remain unmasked during its weapon launch and guidance.

The hovering helicopter, however, may regain cover within very few seconds of a perceived threat, although engagement tactics may require it to "stay on the line" if a missile has been fired. Still, the helicopter's exposure time to threats is typically significantly shorter than for fixed-wing aircraft.

A major conclusion drawn from the exposure statistics gained during the Ansbach trials was that although the intent of the helicopter's hovering tactics was to stand off beyond the range of threat weapons and sensors, terrain and tactics employed by both forces usually precluded complete standoff. Because of this fact, adjacent clutter and minimum exposure times became equally important factors for helicopter effectiveness. That is, high clutter minimized the chance of detection at the exposure range, while brief exposure times could "beat" the threat timeline.

Figure 2 illustrates the distribution of engagement ranges the AH-1's firing TOWs experienced during the Ansbach trials. As the figure shows, half of the engagements occurred at less than two-thirds of the TOW's maximum range. Exposure times were driven by the difficulty in detecting the armor units at these ranges using a moderate and narrow field-of-view optical sight and the time required to fire and guide the tow missile.

The results of the Ansbach trials were a stunning success for validating the effectiveness of the helicopter force because they proved that, at standoff, in terrain, helicopters were very difficult to detect and that helicopters hovering near cover the helicopter could terminate their exposure to risks or engagement at any time. Figure 3 illustrates an attack helicopter masked in terrain.

Reasons for Success

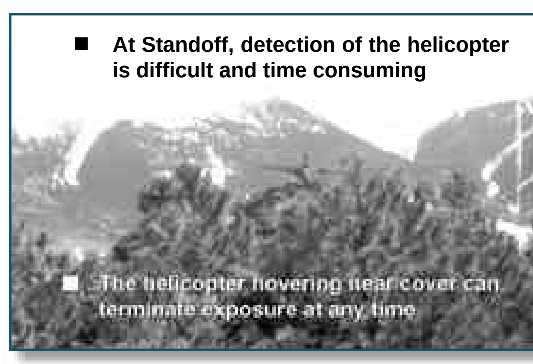

Figure 3. Photograph of the "Stealth" Rotor craft

Following the Ansbach Trails, a series of scout/attack helicopter field trials were conducted throughout the 1970s. Trials at the Combat Developments Experiments

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Center in Fort Ord were conducted with both AH-1 and AH-56 Cheyenne prototypes. These trials examined and quantified the factors involved with, and developed tactics to include, night operations. With Project MASSETER at Fort Hood, Texas, major contributions were made in developing camouflage for helicopters.

The preoccupation with anti-armor systems and close air support in the mid- to high-threat scenario had generated a plethora of competing weapons systems. In response, the Undersecretary of Defense commanded a series of trials in 1978 that would compare "competing" aviation systems. These trials were named TASVAL.

The results of TASVAL showed that despite the significant increase in quality and quantity of air defense threats, scout/attack helicopters still produced significant loss exchange ratios vice the opposing force. Their performance, although somewhat less than that experienced in the Ansbach trials, remained highly effective. The helicopters, even when presented with more modern air defense threats than those used during the Ansbach trials, were difficult to detect. Based on the results of TASVAL, the attack helicopter programs were granted additional funding to continue developing new technologies.

Modern Helicopters

Beginning in the mid-1970s and based on a firm foundation of the lessons learned from the previously conducted trials, the Apache and Hellfire were developed. The Apache was originally required to survive in the presence of the ZSU-23/57, AAA, and SA-7 air defense threats. Meanwhile new technologies, such as a FLIR/ LLTV/Optics target acquisition system and FLIR/IHADS pilots night vision system extended use of the Apache attack helicopters to include night operations. Additionally, the FLIR and the integrated avionics system allowed targets to be acquired within a much shorter timeline, even during the day. Additionally, a significant gun with light armor capability was included with substantial ammunition. Vulnerability reduction techniques were required against small arms up to 23mm HEI and infrared signature reduction was included in the basic design, rather than added on as was the case with prior helicopters.

In the early 1980s, the U.S. Army TRADOC conducted a series of Mission Area Analyses across the breadth of its forces. These analyses examined the mission, threats, technological opportunities, and current plans for improvements in each branch of the service, including aviation. It was decided that within the scout/attack portion of the aviation fleet a new helicopter should be developed that would be a fully night-capable scout for the Apache team in the Heavy Divisions and would replace the AH-1 attack helicopter and OH-58C scouts in the Light Divisions. Thus, development of the LHX/ Comanche began.

Studies on how to fulfill the LHX / Comanche concept focused on three areas—improved sensors and integrated and automated avionics, improved weapons, and reduced signatures. The latter being based on emerging "stealth" technology. To develop the LHX/Comanche's concepts and requirements, extensive analyses and simulations were conducted that applied the key factors learned in previous trials. Specifically, maximum stand-off range in terrain, limited exposure time, firing rate and detectibility, including emerging avionics, computer, sensor weapons, and stealth technology developments were applied to the analyses.

Reduced Signatures

The fundamentals of hovering tactics, stand-off distance, and adjacent terrain clutter all drive the signature reduction requirements involved in creating a significant helicopter combat capability. because of these factors, signature reduction requirements for helicopters is factors less than that required for the F-117, which operates high in the sky without the clutter.

Comanche radar signature reduction was achieved by shaping and materials in the classical

Figure 4. The Comanche RAH-66

way, as Figure 4 shows. Similarly, the infrared signature was reduced by cooling and completely shielding the exhaust and insulating the airframe so that lock-on was difficult to achieve when the helicopter was viewed against the terrain background. Visual signature was controlled by canopy shaping and advanced paints. Acoustic signature was reduced by the use of five, main-rotor blades with swept-tapered-tips and a multi-bladed, shielded fantail anti-torque system.

During the mid-1980s the creation of the Longbow radar target acquisition system and the companion RF seeker Hellfire missile further enhanced the effectiveness of the scout/attack helicopter weapons system.

First, the mast-mounted Longbow radar provided target acquisition in almost all weather, day or night, against multiple stationary and moving targets. This enabled target acquisition, identification, and classification to be accomplished automatically in many conditions providing both detection and prioritization of targets, via exposure of just the sensor.

Second, the RF seeker Hellfire provided a true "fire and forget" missile. No helicopter exposure was required to either launch or guide the Hellfire. Initially, the Longbow/RF Hellfire developments were included into portions of the Apache fleet as the AH-64D. Eventually, these capabilities will be included in Comanche.

More recent developments in the scout/attack helicopter mission technologies include enhancements in communications, navigation, and intelligence. For example, the "Automatic Target Hand-off System" transmits targeting data among the helicopter team via digital burst transmission, whereas integrated GPS/INS navigation provides far greater accuracy in both navigation and the target hand-off process. Additionally, large- scale instrumented field trials have been enhanced significantly by the development of SIMNET and its associated comprehensive Battle Lab war gaming simulations. Perfect intelligence results in the absolute minimum number of exposures, at the optimum location in terms of stand-off, background and field-of-view.

These developments, when they are fully implemented, will improve the scout/attack helicopter engagement parameters. Stand-off ranges for the scout portion of the team will continue to be based on terrain and tactics and are not expected to change much, while attack machines may stand off behind mask at ranges limited primarily by missile range. Overall, exposure times will be shorter. At most tactical ranges, Comanche will be difficult to detect. Further, all this will be accomplished day or night in all weather and should result in combat effectiveness against modern air defense threats that is at least as good as the results achieved in the Ansbach Trials.

Future Considerations

The question of survivability for the scout/attack helicopter system then is not, "Can the scout/attack helicopter weapon system survive on the future battlefield?" but "Will sensors and weapons on the future battlefield exist that will engage and destroy the helicopter?" The answer is it is unlikely. The near- to mid- term development of rapid scanning line-of-sight sensors will not significantly improve the detection of Comanche- like helicopters operating in terrain. There are simply not enough signals available to produce the

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Stealth As A Dependent Variable To EW

by Mr. Paul H. Berkowitz

Although electronic warfare (EW) has existed since the 1940s, low observability (LO) has existed only about half that time. These two technologies have been developing independently, but that is changing. The two technologies are synergistic, but at certain levels of radar cross section (RCS) reduction, EW techniques are enabled, greatly leveraging the survivability achieved with LO. Thus, by treating stealth as a dependent variable to EW, it is possible to optimize affordable solutions.

Historically, achieving airborne survivability has been solely via EW means. Even though the robustness of EW has matured to the point of live fire testing, robust techniques are typically limited to endgame scenarios. These techniques engage only after a missile has been fired. Thus, EW is considered adequate, but not the desired "magic bullet." Most recently, achieving airborne survivability has been solely via LO. Even though the LO F-117 aircraft suffered zero losses in DESERT STORM, at least one-third of the missions were flown with EW support. (According to those scheduling the F-117 missions, EW support was requested for ***every*** mission.) Therefore, LO is also considered adequate, but not a magic bullet. Consequently, the current trend is to use a combination of LO and EW technologies for survivability. This trend is evidenced by programs to backfit LO enhancements to EW-equipped aircraft, and add EW to LO aircraft. This combination offers great synergy.

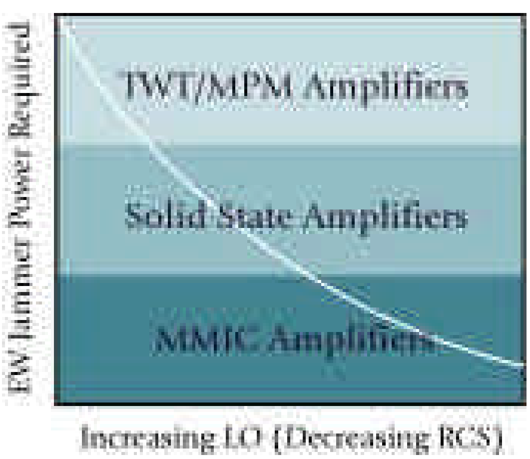

Figure 1. Incremental EW Simplification

LO significantly reduces EW requirements. Because LO can enable avoidance of many threats, the EW system does not have to jam everything in the battlefield. Additionally, the unavoidable threats can be jammed using lower power. Similarly, EW reduces LO requirements. Because EW situational awareness can enable threat avoidance, the aircraft does not have to be "LO" to everything in the battlefield. Furthermore, the robust EW endgame countermeasures can make "statistical" rather than absolute LO acceptable. A 97 percent probability of not being detected, coupled with a 97 percent probability of preventing a missile kill, yields a 99.9 percent probability of survival. Given this synergy, the question becomes how to optimize the integration of LO and EW. Two basic approaches exist: build all the stealth that we can (or cannot) afford, or evaluate LO on its own ***and*** as a function of EW. The premise is that the second approach yields optimum performance at affordable cost.

Let us examine LO/EW interaction as cross section is reduced. The LO payoff versus range is linear; the detection range decreases as the 1/4 root of RCS reduction. EW performance also has a linear component versus RCS. Jamming power reduces by the 1/2 root of RCS reduction. However, EW performance also has incremental improvements at specific RCS thresholds. These improvements include EW system simplification and cost reduction, but more importantly EW system enabling.

Figure 1 illustrates incremental EW simplification. As LO is increased (RCS is decreased), EW power requirements are reduced as the square root of RCS. As the EW power requirement decreases, it crosses important amplifier technology thresholds. The first increment is to

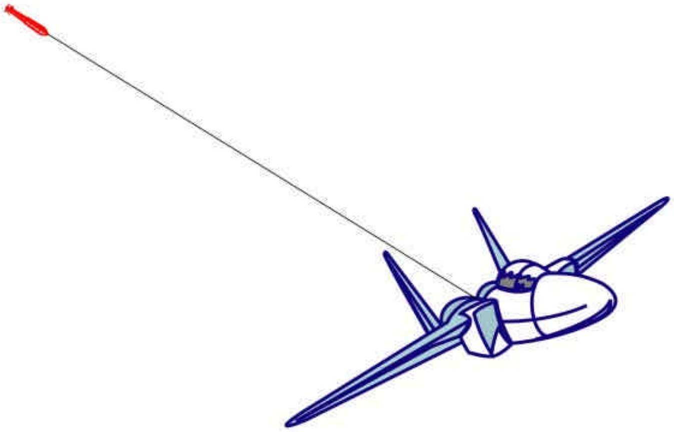

Figure 2. Conventional Decoy on Conventional Aircraft

change from traveling wave tube (TWT) and microwave power module (MPM) transmit amplifiers to smaller, lighter, less expensive solid-state amplifiers. The second increment reduces from solid state to Monolithic Microwave Integrated Circuit (MMIC) components, again with corresponding reductions in size, weight, and cost. This simplification is desirable, but is not dramatic enough to drive LO design. For incremental enabling of EW, however, the payoffs warrant consideration during LO design.

Conventional EW implementation can be either electronically or physically incompatible with LO. For example, a broadband noise jammer is inherently electronically incompatible with LO. Similarly, large EW antennas can physically prevent their usage on LO aircraft. However, incremental cross section reductions can enable EW technologies to be compatible with LO. An example using towed decoy technology will be analyzed.

The baseline is a conventional fighter with a nominal 10 m^2 cross section, using a smart towed decoy, confronted by a typical pulsed I Band surface-to-air-missiles (SAM) radar with a +125 dBm effective radiated power (ERP). At a nominal 5 nautical mile range, using the standard radar range equation with these hypothetical values results in a jamming power requirement of 50 to 100 Watts to achieve the desired jam-to-signal (J/S) ratio. This process requires (TWT) transmitter technology in the decoy. Figure 2 illustrates conventional towed decoy concept.

If RCS is reduced by 10 dB, to 1 m^2 or 0 dBsm, the EW power requirement reduces between 5 and 10 watts, which still requires a TWT transmitter in the decoy. However, this has a potential impact because the decoy physical size can create an echo that competes with the aircraft LO. A typical decoy size measures 16 inches long and 2 1/2 inches wide. The cross section of a simple cylinder is nominally 1 m^2 at I/J Band; with fins and stabilizers, it is larger. As shown in Figure 3 this decoy cross section is clearly incompatible with the aircraft RCS and eliminates a valuable EW asset for this size aircraft.

However, if the RCS can be reduced another 3 dB (to 0.5 m^2) the EW power requirement reduces between 2 1/2 and 5 Watts. This change makes solid-state transmitter technology viable for the decoy. In turn, a much smaller decoy is enabled. Figure 4 illustrates a recent mini-towed decoy design, which is 4 inches long by 1 inch wide. Its cross section is nominally 0.01 m^2 or -20 dBsm at I/J Band, which is clearly compatible with the LO RCS, returning to the aircraft and decoy balance as shown in Figure 2. Thus, this 3-dB increment in LO enables the towed decoy EW and highly leverages the survivability increase of the incremental RCS reduction. Similarly, another 10-dB RCS reduction can reduce the vehicle cross section below the decoy towline power wire RCS, again disabling the use of the towed decoy. Likewise, another 3-dB RCS reduction enables the delivery of power to the decoy via a fiber optic line, eliminating the metallic tow line wires and their cross sections. Again, the incremental 3-dB RCS reduction enables the valuable towed decoy EW. Furthermore, RCS reductions can enable not only additional towed decoy-size reductions but also unpowered decoys, which simply launch the RF signal from the tow line into an antenna without an amplifier.

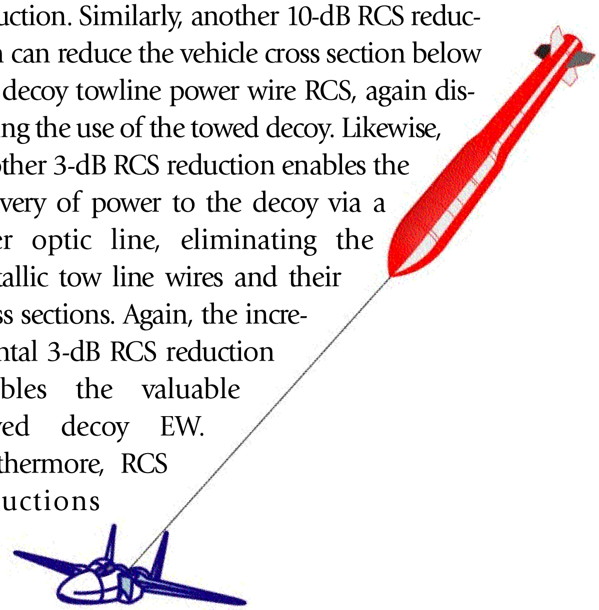

Figure 3. Conventional Decoy on LO Aircraft

As is demonstrated in the towed decoy analysis, the LO/EW interaction can be somewhat complex. Incremental RCS levels can either disable or enable the use of towed decoy. This important factor must be considered during LO design.

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The Survivable Rotorcraft

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signal-to-clutter levels that will allow detection in the brief timeline afforded the air defense sensor.

And although imaging-type sensors that could detect a Comanche-like target are clearly feasible, their timeline is, for the foreseeable future, too long to engage the fleeting targets. Non-line-of-sight imaging sensors, such as those developed for UAVs also require significant timelines and relatively narrow field-of-view. Additionally, detection of camouflaged fleeting targets will require a very large number of non-line-of-sight imaging sensors. Because these imaging sensors will become vulnerable, if not low-observable themselves, this approach is not optimum.

Consequently, any such solution is probably unaffordable by any nation for the foreseeable future. And because of this, today's modern helicopters can be expected to continue their role as a highly effective scout/attack weapons system in the future battlefield. ✥

Biographies

Mr. Harding is the Director, Future Programs, Advanced Rotorcraft Systems, The Boeing Company. During his 36 years with Boeing, he has worked on the design and development of the CH-47, CH-46, HLH, LIT, A-X, UTTAS, AAH, ASH, HSM and Commercial Chinook programs. Mr. Harding has specialized in the design and analysis of helicopter survivability and combat effectivenss features.He may be reached at 610.591.8700.

Mr. Brumley presented "Rotorcraft Survivability: The Role of LO and EW Technologies" at the Low Observables and Countermeasures Symposium in August 1998.

Stealth As A Dependent

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Similar increments exist for other EW techniques. On–board techniques, such as Cross Eye Cross Polarization, require hundreds of Watts of power for conventional–size aircraft. This technique requires TWT transmitters, ferrite components, and waveguide transmission lines, all of which add significant size, weight, and cost. Furthermore, Cross Eye may require a large baseline separation between antennas, which for conventional aircraft is about 75 feet. None of these factors are conducive to installation on an LO vehicle. However, a 25-dB reduction in RCS eliminates the need for TWTs, ferrites, and waveguide, enabling an all-solid-state component and cable implementation. In addition, the

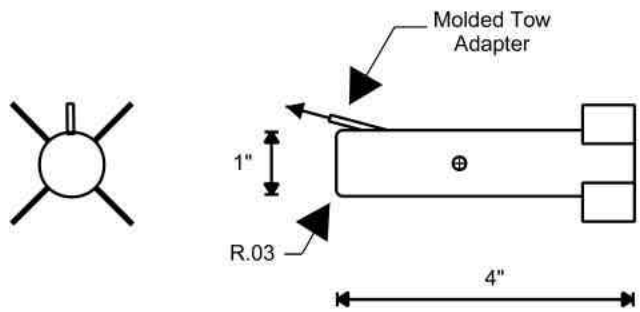


Figure 4. Mini Towed Decoy

antenna separation requirement for Cross Eye is reduced to 18 feet. This RCS reduction significantly enhances the feasibility of robust Cross Eye Cross Polarization EW. Another 10-dB RCS reduction enables an all-MMIC solution and 10-foot Cross Eye separation, further increasing robust Cross Eye/Cross Polarization EW feasibility.

In summary, it has been determined that many interactions between LO and EW are incremental. This incremental relationship offers significant opportunities for optimization. The LO payoff can be multiplied at EW enabling increments. To exploit these opportunities, it is necessary to evaluate LO in context of its EW impacts during the initial design phase of a program. Thus, treating stealth as a dependent variable to EW will lead to optimum affordable solutions. ✥

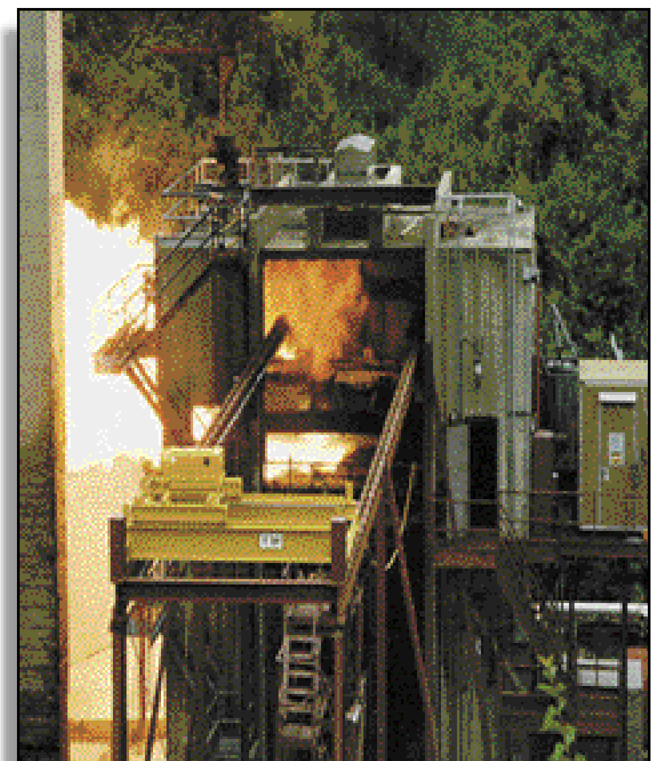
Biography

Mr. Berkowitz has worked in the EW community for over 30 years and is currently Executive Vice President of Electro-Radiation Inc. in Fairfield,NJ. His EW experience extends from B-52 to B-2, F-4 to F-22, and MH-47 to SR-71. His LO background includes DARPA studies as well as EW for Stealth aircraft. Mr. Berkowitz received a B.S.E.E. from Rutgers University in 1968. He may be reached at 973.808.9033.

NDIA Aircraft Fire and Explosion Information Exchange Meeting

by Mr. Ralph Lauzze
Mr. Chuck Pedriani
Mr. Dale Atkinson

The National Defense Industrial Association (NDIA) sponsored a Fire and Explosion Information Exchange Meeting on October 21, 1998 at the Defense Logistics Agency Headquarters, Ft. Belvoir VA. The meeting was arranged by the Combat Survivability Division of the NDIA (formerly ADPA) to explore how the agencies working in fire and explosion research might come together to make progress in this important area by leveraging off each other's initiatives for the common good. Participants included speakers representing the FAA, NTSB, NASA, Office of the Secretary of Defense, Army, Navy, Air Force, Department of Energy, Department of Commerce, and industry.



Military and civil aviation share a continuing interest in reducing aircraft hazards from fire and explosion. Historically, fuel fire and explosion have been the leading cause of combat aircraft losses. Fire is one of the major contributors to aircraft incidents in civil aircraft, and the TWA 800 accident has brought fire and explosion concerns to the forefront in transport aviation. Consequently, reducing fuel fire and explosion hazards is a matter of interest throughout the aviation community.

The thrust of the meeting was to review the fuel fire detection, suppression, and explosion mitigation needs for military and civil aviation and foster ways to expedite development and transition of technology to the aviation fleets. The presentations and discussions were tailored toward exploring potential for cooperative approaches to focus and accelerate development and leverage resources.

Mr. Ralph Lauzze, Chairman of the meeting, convened the conference and introduced Admiral Robert Gormley, USN (ret), Chairman of the Combat Survivability Division, who provided the Introduction and Purpose of the meeting. The Guest Speaker, Dr. Patricia Sanders, Director, Test, Systems Engineering and Evaluation, Office of the Under Secretary of Defense for Acquisition and Technology, set the tone for the meeting by stressing that sharing information was not enough, that truly cooperative programs would be necessary to solve the aircraft fire and explosion issue.

The initial speakers provided a broad perspective of fire problems from different developmental and operational perspectives. Mr. Ronald Mutzelberg, Deputy Director for Air Warfare in the Office of Strategic and Tactical Systems, Under Secretary of Defense for Acquisition and Technology, provided an overview of the military perspective of aircraft fire and explosion problems. Dr. Vernon Ellingstad, Director of the Office of Research and Engineering, National Transportation Safety Board, provided an overview of the civilian perspective. Mr. Eric Schwartz, Executive Assistant to the Chief Engineer, The Boeing

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Company, presented a comparison of civilian and military views, citing the resulting differences in hardware solutions to the fire hazard problems. Mr. Richard Hill, Program Manager, Aircraft Fire and Cabin Safety, Federal Aviation Administration, presented the results of the recent Aviation Rulemaking Advisory Committee (ARAC) study examining explosion hazards and potential solutions.

The remaining presentations included details covering a wide range of active programs addressing the many facets of the fire and explosion hazard. The Services, FAA, NASA, and industry perform active research and development programs to address the fire problem as manifested in their air systems and operational environment. NASA is the focal point for a new initiative to make a dramatic reduction in the civil accident rate. The Next Generation Fire Protection Program (NGP), is pursuing a replacement for Halon 1301. In response to the TWA 800 accident, the NTSB is overseeing a fuel explosion research program aimed at determining the cause of the of the TWA 800 explosion.

In spite of the wide range of aircraft systems, missions, and basic operational objectives represented at this meeting, there were many common threads throughout the presentations. Many presenters stated that, at the heart of developing a better understanding, there is a need for better modeling and simulation technology at both ends of the spectrum - precise physics based models to evaluate phenomena, and somewhat less rigorous engineering models to be used in system design and development. In addition, more widely accepted and validated development and test methods are needed that can be correlated to basic physical principles.

At this time, there is no established forum specifically for the coordination of fire and explosion technology development. Much of the coordination currently occurs on an ad hoc basis. There are many common needs within the technology that can be used as the basis for more information exchanges and, possibly, cooperative programs. A structure for the exchange and coordination of fire and explosion information and programs could reduce development time, avoid duplication, and result in better solutions. Focused research, directed at knowledge and technology voids, common to all air platforms would facilitate the development of fire and explosion protection for all aircraft and save lives.

The participants agreed that, as a first step, DOD should take measures to centralize the information describing the work being performed by its organizations. A single point of contact is needed to facilitate coordination between DOD efforts, and those initiated outside DOD. As a result of this discussion, the JTCG/AS will take action to act as the "single face to the customer" for DOD fire and explosion research. Secondly, the NDIA should sponsor a workshop to develop a similar centralized way of coordinating programs between DOD and other organizations in the civil sector. The workshop could also develop prioritized goals that would form the basis for potential joint programs. For additional information, or comment, on the initiative to coordinate efforts in aircraft fire and/or explosion research, please contact one of the authors listed above, or the JTCG/AS Central Office. ✦

Biographies

Mr. Lauzze received a B.S. in Mechanical Engineering from Purdue University and an M.S. in Mechanical Engineering from the University of Dayton in 1982. Ralph is the AFRL aircraft vulnerability Test Director for Live Fire Test and Evaluation (LFT&E). Ralph is the Air Force Principal Member to the tri-service Joint Technical Coordinating Group on Aircraft Survivability, and is currently its chairman. He may be reached at 937-255-6823.

Mr. Pedriani received his B.S. in Mechanical Engineering from Pennsylvania State University in 1966. He is a project engineer with SURVICE Engineering Company, serving as principal investigator and team leader in projects involving live fire testing, survivability design, system requirements, susceptibility reduction, and vulnerability reduction. He may be reached at chuck@survice.com.

Mr. Atkinson is a consultant in the aircraft combat survivability area. He retired from the Office of the Secretary of Defense in 1992 after 34 years of government service and remains active in the survivability area. Mr. Atkinson played a major role in establishing survivability as a design discipline and was a charter member of the tri-service JTCG/AS. He was also one of the founders of the DoD Survivability/Vulnerability Information Analysis Center (SURVIAC). He may be reached at 703.451.3011.

The Synergy of Susceptibility Reduction and Signature Management: A Question of Energy

by Mr. Larry DeCosimo

If a single key parameter had to be identified that was critical to all aspects of susceptibility reduction, that parameter would be jammer to signal (J/S), the ratio of the jamming power to the signal power. Regardless of where the system is operating within the electromagnetic spectrum, from radio frequency (RF) through infrared (IR) into the ultraviolet region, the most critical factor to be considered for jamming effectiveness is the J/S ratio. The higher the ratio, the more likely that the countermeasure will work. Many earlier attempts to provide susceptibility protection to a platform took a "stovepipe" approach increasing the jammer's power. The current trend is to take a broader approach and work with both elements of the equation: the susceptibility reduction portion (the numerator) and the signature management portion (the denominator). This approach yields significantly more survivable solutions that are technically sophisticated and cost effective.

U.S. helicopters first encountered IR missiles in Vietnam. It was a new and frightening experience when helicopters seemed to simply fall from the sky. Once it was learned that heat-seeking missiles were causing the problem, the solution was simple: get rid of the heat. That problem was solved by installing an exhaust diverter. The exhaust diverter funneled the exhaust up into the rotor wash to dissipate the heat and also blocked the view of the turbine that was visible up the engine tailpipe. For that generation of missiles, this was a very simple and sophisticated solution. These missiles needed a very high temperature source for acquisition and tracking. The pilot only had to remember to make pedal turns and not bank the aircraft. Banking the aircraft would expose the engine's hot metal parts, providing an easy target for the missile. This type of approach is now outdated because newer missiles have an-all aspect capability. Their seekers are designed to work in an IR region that can lock on to the skin as opposed to the hot metal parts of an aircraft.

Having learned from this experience, the next generation of aircraft included signature management in its basic design. An example of this integrated approach is the U.S. Army's Apache Attack Helicopter, the AH-64. Its IR suppression was designed as an integral part of the entire aircraft, especially the engine. When it came time to develop the active jammer for this aircraft, the job became significantly easier. Based on the Apache's radiated signature, it was estimated that a jammer with an input power of 1500 watts could provide adequate countermeasures effectiveness. The system developed was the AN/ALQ-144A. This 26.5-pound system, which consumes 1.3 KVA of total power, provides protection against some of the latest generation missiles.

As aircraft get larger, so does the problem of providing survivability. Designers have to become more ingenious, or the platform will begin to suffer in regard to load-carrying capability and mission range. For example, the Army's Blackhawk UH-60 helicopter, could not be suppressed to the same levels of the Apache. Consequently, a single AN/ALQ-144A would not provide adequate coverage. The project leader for the jammer devised a solution that was relatively simple mechanically, yet sophisticated from an engineering aspect. Two AN/ALQ-144As were phase locked so that their jamming power could be added to provide twice the capability of a single unit. This change gave more than adequate protection to the aircraft.

For other aircraft, it has not been possible to develop effective suppression tech-

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niques without placing an unacceptable weight and performance penalty on the aircraft. An example is the Army's CH-47 Chinook, which is comparable to the Marine Corps' CH-46 Sea Knight. The Army has tried unsuccessfully to develop an engine suppressor for this aircraft. The latest attempt yielded a design that weighed 300 pounds per side and consumed more than 2 percent of the engine's power. Although this solution was not feasible and had to be abandoned, other experiments are under way to use different concepts to develop a viable suppressor. Even though it has not been possible to develop viable suppressors, aircraft have not been left unprotected. Other approaches needed to be employed to reach the desired J/S ratio. The Army and Navy developed systems to protect these helicopters.

The Navy's Approach

The Navy's approach was to develop the AN/ALQ-157 infrared jammer to protect the Sea Knight. This 220-pound system consumes 8.5 KVA of power. A "negative synergism" comes into play when these types of systems are mounted on an aircraft. Larger systems require a stronger and heavier installation kit. Higher power consumption means that heavier gauge wiring must be used, which only increases the weight. Higher system weight and power consumption require additional engine horsepower and have a negative effect on weapons payload and platform range.

The Army's Approach

The Army took a different approach to platform survivability by developing the AN/ALQ-156 missile approach detector for protection of its Chinook. The Army developed a pulse doppler radar that detects a missile's approach and launches a flare to decoy the missile. However, a drawback is that it is an active system that increases RF emissions from the platform. (For many applications, the AN/ALQ-156 has been replaced by the AAR-47 passive missile warning receiver.)

The problem continues to this day, regardless of whether expendables or active jammers are considered. The major difference between Army and Air Force flares is in their size. Larger signature aircraft require larger flares to accomplish the same results. Army flares measure 1 inch x 1 inch x 8.5 inches. Comparable Air Force aircraft flares are 1 inch x 2 inches x 8.5 inches or 2 inches x 2.5 inches x 8.5 inches. This increased size means that either more or significantly larger dispensers would be required to launch the same number of flares. The same problem exists for laser-based jamming.

Lasers are available that can provide suppressed aircraft with J/S ratios in the 1,000s. These lightweight, 18-pound lasers can be carried by small aircraft, such as helicopters. Because of the large J/S ratios they provide, generic waveforms can be used to defeat a wide range of the newer threat missiles. However, when these same lasers are placed on aircraft having large signatures, the J/S drops precipitously, as does its ability to break–lock a missile. The accuracy of the jamming waveform now becomes increasingly critical, and miss distances begin to diminish. Two approaches being pursued are to either develop larger lasers or to attempt to diminish the aircraft signature. The benefit to pursuing both approaches is that the platform will not be locked into a single approach; rather the most affordable approach can be selected. ✦

Biography

Mr. DeCosimo has 15 years experience developing survivability equipment for U.S. Army platforms. This has included RF and EO systems as well as infrared countermeasures. He is currently responsible for hardware development for the Tri-service Advanced Threat Infrared Countermeasures/Common Missile Warning Receiver program. He may be reached at 732.427.4261.

Two Long-Time JTCG/AS Industry Advisors Receive Special Honors

by Mr. Joseph P. Jolley

Nikolaos Caravasos

Mr. Nikolaos (Nick) Caravasos was recently honored as recipient of the American Institute of Aeronautics and Astronautics (AIAA) Survivability Award during the awards banquet at the World Aviation Congress & Exposition being held in Anaheim, California on 29 September 1998. The Survivability Technical Committee of the AIAA unanimously selected Mr. Caravasos for this year's award for his contributions in the areas of design, analysis, implementation, and education, which have clearly separated him from his peers in the advancement of survivability as a design discipline.

Nick has been involved with aircraft design and survivability for over 30 years with Boeing Information, Space, and Defense Systems, Philadelphia, Pennsylvania. He is recognized as an expert, nationally and internationally, on survivability matters having worked on programs such as: YUH-61A (UTTAS), HLH, RAH-66 Comanche, V-22 Osprey, F-22, and JVX aircraft. He continues to do research in new materials and processes, hydrodynamic ram, and blast damage effects among others. He was previously honored as the top IR&D producer at Boeing Helicopters in 1985, 1986, 1987, and 1988. He has managed numerous Army, Navy, & Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) contracts, and is currently managing two such contracts.

Nick is an Associate Fellow of the American Institute of Aeronautics and Astronautics, a charter member of their Survivability Technical Committee (serving as chairman in 1992 and 1993), a member of the American Helicopter Society, and an industry advisor to the JTCG/AS. He has published and presented numerous articles on aircraft combat survivability, repairability, and crash worthiness. He has also given several invited lectures on "Aircraft Combat Survivability", "Helicopter Design", and "Live Fire Testing". ✦

Michael Meyers

Michael Meyers, a leader in developing the survivability of the F-4, F-15 and F/A-18A/B, has been selected a Boeing Technical Fellow, an award to recognize and promote technical excellence.

At Boeing, formerly McDonnell Douglas Aerospace, Mike has been Vulnerability Team Leader for the F/A-18E/F since 1991. His responsibilities include vulnerability analysis, design interface, live fire testing, and trade study evaluations.

From the mid-1970s into the mid-1980s, Mike led evaluations of the F/A-18 Hornet survivability design. Studies included signature reduction analyses, countermeasure effectiveness evaluations, and a laser vulnerability and hardening analysis.

Earlier, Mike was responsible for the F-15 vulnerability/survivability program from conceptual design to production. During this time, he formulated the vulnerability estimating methodology and the associated survivability modeling techniques used for design evaluations.

Mike earned his B.S. in electrical engineering from Washington University in 1960 and worked on design and evaluation of advanced electronic equipment for the Radio Physics Laboratory at the Naval Research Laboratories in Washington, DC, before joining McDonnell Aircraft Company in 1962. ✦

Active Core Exhaust Control Systems

by Mr. Clarence F. Chenault and
Dr. Yvette S. Weber

A major concern for many military heavy-lift cargo and transport aircraft is the undesirable effects hot exhaust gases have at various points in the flight regime on structural integrity, human effectiveness, and aircraft survivability. During powered descent and takeoff, hot gas impingement can damage trailing edge flaps. During off-load operations, ambient temperatures at the rear of the aircraft can rise to unsafe levels for sustained manual labor. In all phases of the flight, the hot plume and engine components increase an aircraft's vulnerability to heat seeking missiles.

Techniques to overcome each of these problems are available, but a balanced solution is often difficult to attain. Split flap designs and high-temperature titanium alloys can help maintain an aircraft's structural integrity; however, split flaps generate less lift than single flap designs, and titanium alloys are heavier and more costly than aluminum alloys. A core thrust reverser can be used to control the ambient temperature at the rear of the aircraft during off-load operations by deflecting the hot gases away from personnel. However, the hot gas deflection to other airframe structures may require additional thermal protection. A core reverser also adds weight, complexity, and correspondingly higher maintenance to an aircraft and may preclude the use of a plug nozzle or obscuration device.

The Air Force Research Laboratory (AFRL), under contract with the Boeing Company, has investigated the use of pulsed injection to trigger self-sustained mixing of jet exhaust plumes. The system uses a small amount of engine bleed pulsed at key frequencies to destabilize the plume. This results in a periodic flapping of the plume that entrains ambient air and enhances the mixing effectiveness of the system. Such a system, termed Active Core Exhaust (ACE) Control System was recently tested in a full-scale engine ground test with the ACE system installed on a Pratt and Whitney JT8D-15A at Pratt and Whitney's C-11 commercial test facility in West Palm Beach, Florida, as shown in Figure 1.

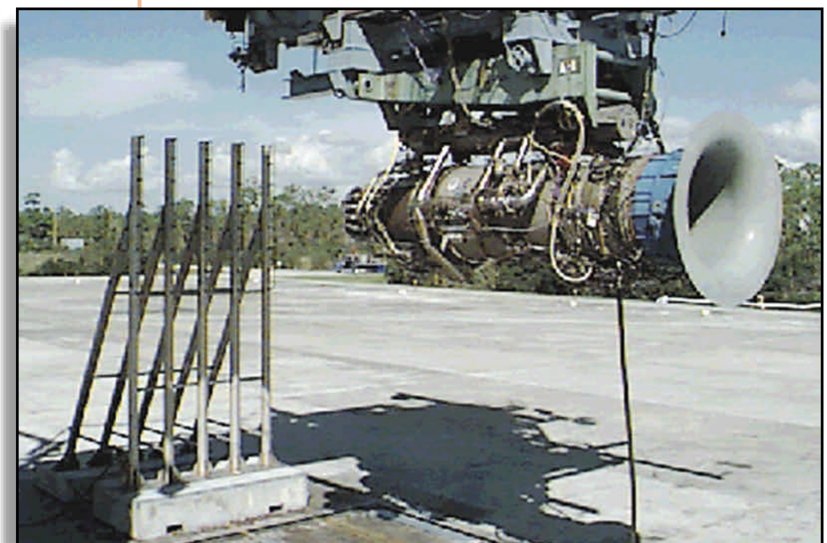

Figure 1. Full-Scale Low-Bypass Ratio Aircraft Engine

The ACE JT8D test configuration was developed to ensure maximum flexibility in varying injection flow rate, frequency, and velocity, and in injector slot size, orientation, and geometry. Injection flow was provided via the 8th and 13th stage bleed ports, and a fluidic actuator valve was developed to provide injected pulses at a wide variety of frequencies. Injection slots,

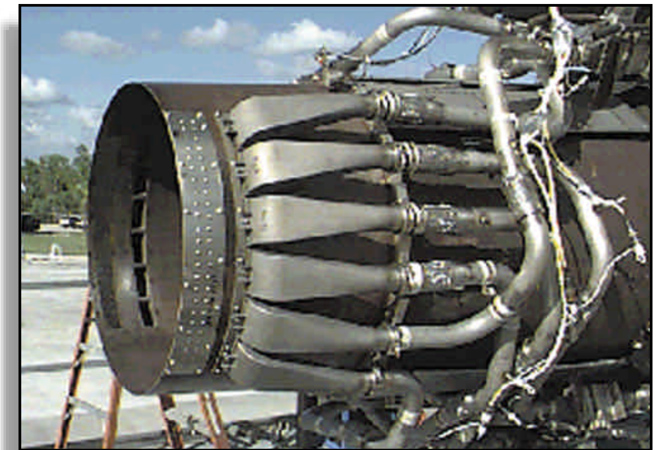

Figure 2. ACE Control Installed

which were positioned 180 degrees opposite each other, had injection characteristics varied with removable "jet blocks" to change the slot sizes. Two injector positions, fore and aft, near the nozzle exit could evaluate the effectiveness of the injection when it was applied upstream of the nozzle exit plane. In addition, the nozzle could rotate 90 degrees about the longitudinal axis to obtain data for flapping in the horizontal and vertical planes. Figure 2 shows the injectors mounted in a horizontal position at the upstream nozzle injector port. The ACE JT8D test hardware was designed for flexibility under considerable cost constraints. Optimized, flight-worthy configurations are the subject of follow-on activities.

The test program demonstrated strong mixing under most of the test conditions. Self-sustained exhaust plume mixing resulted in a 50 percent temperature reduction along the exhaust plume centerline in as few as five nozzle diameters downstream of the exhaust exit plane. The test validated that mixing effectiveness improves as the injection is placed closer to the exit plane of the nozzle.

Figures 3 and 4 illustrate dramatically the efficiency of the flapping mechanism in reducing plume temperatures. Figure 3 contains a computationally derived image of the undisturbed plume and a cross-sectional temperature field derived from experimental rake data 5 diameters downstream of the nozzle exit. Figure 4 shows a similar set of images at a snapshot in time with the ACE system turned on. This figure illustrates the resulting flapping motion and temperature reduction of the plume. Also evident is the alteration of the plume shape. The plume disperses in the

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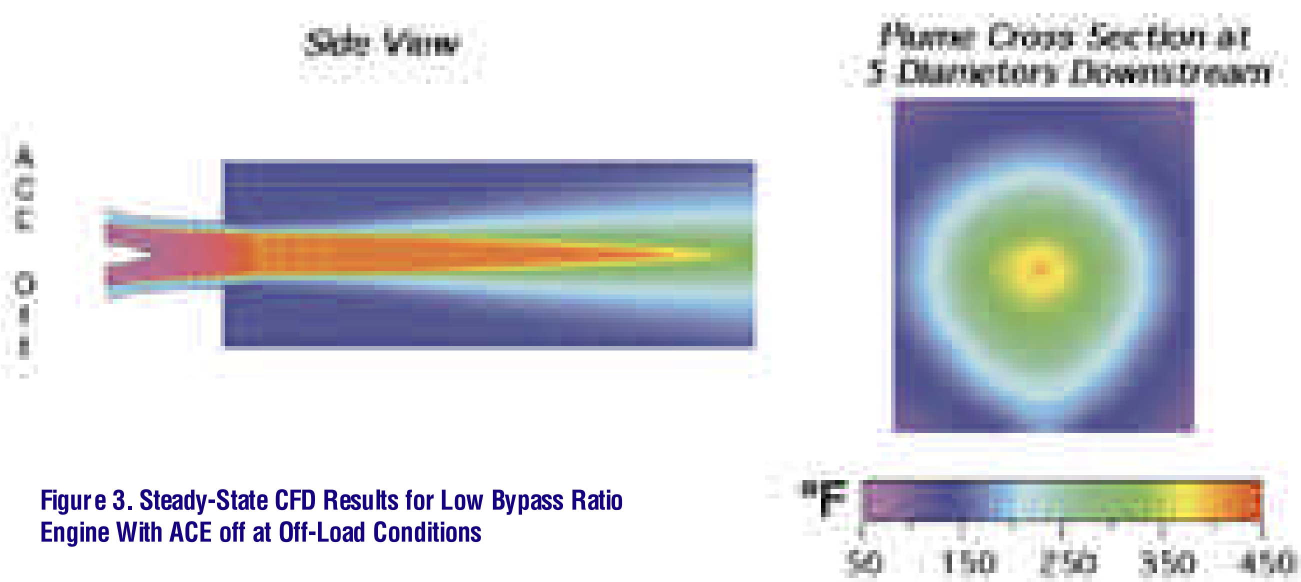

Figure 3. Steady-State CFD Results for Low Bypass Ratio Engine With ACE off at Off-Load Conditions

National MANPADS Workshop: A Vulnerability Perspective

by Mr. Joseph P. Jolley

The National MANPADS Workshop was held 15-17 December 1998 at the Sparkman Center, Redstone Arsenal, Alabama. The classified workshop brought together over one hundred experts for a technical interchange on the issue of how to make aircraft less vulnerable to the MANPADS (Man Portable Air Defense System) threat. Under the sponsorship of OUSD(A&T)S&TS(AW), the workshop was co-hosted by the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) and the Defense Intelligence Agency's Missile and Space Intelligence Center (MSIC). Workshop objectives were to:

- Gather and exchange information concerning aircraft-MANPADS encounters,
- Compile a roadmap of current MANPADS vulnerability reduction activities, and
- Identify vulnerability reduction solutions effective against MANPADS threats.

The results of this workshop are contributing to a one year study, now underway, with similar objectives. The study is scheduled to be completed June 99.

Avoiding the threat using susceptibility reduction techniques such as signature reduction, countermeasures, tactics, etc are recognized as the first line of defense against the MANPADS. However, vulnerability reduction techniques also provide needed protection and constitute a second line of defense which contributes to the overall survivability of the aircraft. The proper mix of susceptibility reduction and vulnerability reduction features will be contingent on aircraft type and mission.

After welcoming remarks and an overview of the MSIC organization and mission by its commander, Col John Wigington, three excellent presentations by key OSD sponsors followed. Dr. Patricia Sanders, OUSD(A&T)DTSE&E, provided the keynote address. Mr. Ron Mutzelburg, OUSD(A&T)DS&TS(AW) and sponsor of the workshop, provided the background and basis for concern with the vulnerability of aircraft to MANPADS given the current emphasis on stealth and low observables. And Mr. Jim O'Bryon, OSD/DDOT&E/LFT, addressed the MANPADS threat from the operational test and live fire test perspective.

A highlight of the workshop was hearing the combat experiences of three pilots who encountered the MANPADS threat during Desert Storm. During the workshop, speakers from government and industry described the proliferation and lethality of MANPADS, susceptibility reduction limitations, and the need to incorporate vulnerability reduction into aircraft designs. In addition, three break-out sessions concentrated on specific subjects including vulnerability reduction techniques, assessment methodologies, and test facility capabilities.

The Results

Preliminary findings from the workshop are listed below.

1. MANPADS are a lethal threat, proliferated worldwide in large numbers. This shoulder-launched weapon system is a serious threat to all types of aircraft.

2. A MANPADS hit does not necessarily equate to a kill.

3. There is a need for MANPADS threat characterization and test databases to support development of improved assessment methodologies and new vulnerability reduction techniques

4. Models have limited capability to predict surface-to-air missile hit locations. Specific improvements are needed in IR signature models and threat-in-the-loop software. Modeling requirements need to drive tests performed and data collected.

5. Current MANPADS test facilities are generally adequate and no major investments are required. Exceptions relate to shotline control and handling large transport-sized aircraft or components.

Summary

MANPADS have become a highly proliferated threat and are lethal against all air platforms. Vulnerability reduction techniques offer a second line of defense after signature reduction, countermeasures and other threat avoidance techniques. Aircraft survivability is optimized by designing in the right combination of susceptibility and vulnerability reduction features, based on the aircraft type and mission, not only for the MANPADS threat, but all types of threats.

Workshop proceedings are being published in two volumes. Volume One is unclassified and contains the agenda, a list of attendees, and the unclassified presentations. Volume Two is classified SECRET and contains the classified presentations. A copy of the proceedings can be obtained by contacting SURVIAC at 937.255.4840 or DSN 785.4840. ✦

Biography

Mr. Jolley is the Deputy Director of the JTCG/AS. He holds a B.S. degree in Aerospace Engineering from the U. of Florida and an MA degree in Public Administration from Wichita State University. Prior to coming to the Central Office in 1990, Mr. Jolley served for six years in the Propulsion and Power Division of the Naval Air Systems Command. He may be reached at 703-607-3509, ext 14.

Pioneers of Survivability

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established and chaired the DOT&E Tri-Service Coordinating Group for this area.

Hugh retired from civil service in 1988. Two weeks after retirement, he joined ASI Systems International (ASI-SI) as a vice president responsible for all ASI-SI Navy programs and later became Executive Vice President. ASI-SI was acquired by SRS Technologies in January 1998. Hugh is the Vice President of ASI-SI, a wholly owned subsidiary. He has been directly involved in Live Fire T&E for the HARM Improved Warhead Program and the Advanced Bomb Family, risk management planning and systems engineering for weapons development programs. In addition to his corporate responsibilities, he supports the Joint Electronic Combat test using Simulation (JECSIM) Joint Test and Evaluation (JT&E) Program.

Hugh has received a number of awards and citations including the following:

- an award for outstanding support to the JTCG/ME and the Army from the chairman of the JTCG/ME
- Certificate of Merit from the Joint Logistics Commanders for outstanding service in joint service activities
- Navy Superior Civilian Service Award in recognition of contributions and support to the Navy and to the defense of the Nation from the Commander, Space and Naval Warfare Systems Command
- numerous Naval Weapons Center awards.

Hugh and his wife Sondra, whom he married in October 1956, have raised three daughters, Sheri, Cathi, and Cindi, and one son, Jeff. When Hugh is not working, he and Sondra spend time with their children and seven grandchildren and visit their second home (the cabin) located at an altitude of 6000 ft. in the Sequoia National Forest, 90 minutes driving time from home. ✦

Active Core Exhaust Control Systems

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direction of the injection, forming an oval rather than a circular cross section. The redistribution of temperature and corresponding pressure loads may have some beneficial effect on the aerodynamic performance of a blown flap system.

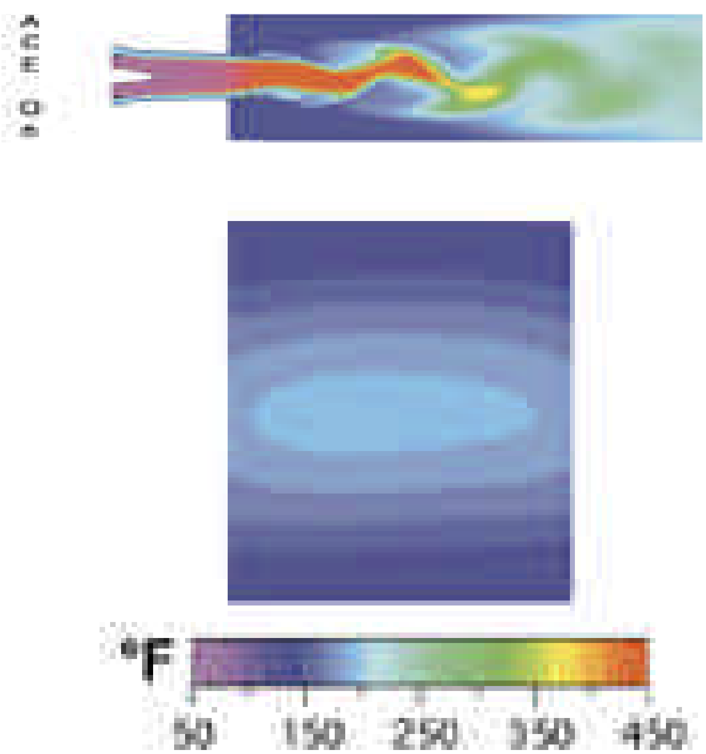

Figure 4. Snapshot of Unsteady CFD Results for Low Bypass Ratio Engine With ACE on at Off-Load Conditions

Although exhaust plume mixing is not a new idea, it has always been accomplished with intrusive devices that degrade engine performance over the entire flight regime. In contrast, the ACE Control System can be switched on and off as needed with no thrust penalty in the off position. The system has the advantages of reducing hot gas impingement on aircraft surfaces during specific portions of the flight envelope and in mitigating a potentially hazardous environment for ground personnel operating in exhaust washed areas of an aircraft without resorting to a core thrust reverser solution. ✥

Biographies

Captain Clarence Chenault graduated from the Air Force Institute of Technology with his Ph.D. in 1998 and Masters in 1993, both in Aeronautical Engineering. He earned his B.S. in Aerospace Engineering from the University of Missouri-Rolla in 1990. Capt Chenault has performed basic research in the application of numerical simulation of high speed injection flowfields using second-order Reynolds stress turbulence models. More recently, he has worked in the Air Frame Propulsion and Weapons Integration Branch of the Air Force Research Laboratory as the senior military computational fluid dynamics analyst and Airframe Integration Engineer for Advanced Exhaust Systems. Captain Chenault may be reached at 937.255.6207.

Dr. Yvette Weber graduated with her Ph.D. from the University of Maryland in 1994. She has been employed by the US Air Force Research Laboratory (formerly Wright Laboratory) since 1992. Yvette has performed basic research in high temperature gas dynamics and the application of computational fluid dynamics to computational electromagnetics. More recently, she has worked in the Air Frame Propulsion and Weapons Integration Branch as the technical lead for Advanced Exhaust Systems. She currently manages Air Force technology programs related to fluidic jet control for mixing, area control and thrust vectoring, the objectives being to provide lightweight, affordable and highly survivable mission critical performance for military aircraft. Yvette has also recently been appointed Chief of the Focus Area on Uninhabited Air Vehicles for AFRL Air Vehicle Directorate. Dr. Weber may be reached at 937.255.6207.

Calendar

MAR

March 29-April 1, 1999, Monter ey, CA
Ground Vehicle Survivability
Contact: 703.522.1820, iclick@ndia.org

APR

April 11-15, 1999, San Diego, CA
High Performance Computing
Contact: Dr. Adrien Tetner 619.277.3888, tetner@anl.gov

April 22-23, 1999, London
1999 Combat Aircraft Survivability Conference
Contact: Steve Philpott - hsauk@aol.com, 44.171.413.0936

MAY

May 11-13, 1999, Kelly AFB, TX
1999 HAVE Forum
Contact: Capt. Wayne Floyd 937.255.0276, http://www.aochq.org

JUN

June 15-18, 1999, Colorado Springs, CO
DDEAF-CRAB Model Users Group
Contact: Geri Bowling 937.255.4840, DSN 785, gbowling@surviac.flight.wpafb.af.mil

NOV

November 16-18, 1999, Monter ey, CA
Aircraft Survivability
Contact: 703.522.1820, jhylan@ndia.org

Information for inclusion in the Calendar of Events may be sent to:

SURVIAC
Washington Satellite Office
Attn: Christina McNemar
3190 Fairview Park Drive, 9th Floor
Falls Church, VA 22042
PHONE: 703.289.5464
FAX: 703.289.5467

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